Purpose: We developed a better method of accounting for the effects of heterogeneity in convolution algorithms. We integrated this method into our GPU-accelerated, multi-energetic convolution/superposition (C/S) implementation. In doing so, we have created a new dose algorithm: heterogeneity compensated superposition (HCS).

Methods: Convolution in the spherical density-scaled distance space, a.k.a. C/S, has proven to be a good estimator of the dose deposited in a homogeneous volume. However, near heterogeneities electron disequilibrium occurs, leading to faster fall-off and re-buildup than predicted by C/S. We propose to filter the actual patient density in a position and direction sensitive manner, allowing the dose deposited near interfaces to be increased or decreased relative to traditional C/S. We implemented the effective density function as a multivariate first-order recursive filter. We compared HCS against traditional C/S using the ICCR 2000 Monte-Carlo accuracy benchmark, 23 similar accuracy benchmarks and 5 patient cases. For the patient cases, we created custom routines capable of using the discrete material mappings used by Monte-Carlo. C/S normally considers each voxel to be a mixture of materials based on a piecewise-linear density look-up table.

Results: Multi-energetic HCS increased the dosimetric accuracy for the vast majority of voxels; in many cases near Monte-Carlo results were achieved. HCS improved the mean Van Dyk error by 0.79 (% of D<sub>max</sub>) on average for the patient volumes; reducing the mean error from 1.93 %|mm to 1.14 %|mm. We found a mean error difference of up to 0.30 %|mm between linear and discrete material mappings. Very low densities (i.e. <0.1 g / cm<sup>3</sup>) remained problematic, but may be solvable with a better filter function.

Conclusions: We have developed a novel dose calculation algorithm based on the principals of C/S that better accounts for the electron disequilibrium caused by patient heterogeneity.

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